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Project Summary

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Overland Flow Treatment of Poultry Processing Wastewater in Cold Climates

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Land treatment of wastewater using overland flow methods has been effectively used in warm climates. A full scale wastewater treatment facility was evaluated, including overland flow in northern Indiana, a cold climate. The study emphasized the evaluation of the overland flow system, but the treatment system included mechanical pretreatment facilities, a storage lagoon, a lagoon for batch chemical treatment of the overland flow effluent and rapid infiltration for effluent disposal. The facility treated wastewater from a duck processing plant. That wastewater was as amenable to biological treatment as domestic sewage and had similar concentrations of nutrients and solids.

Overland flow systems typically are limited to low permeability soils. This system was located on a sandy loam soil with very high permeability. Bentonite was used to provide a percolation barrier below the grass covered surface.

The Project Report describes the design and construction of the facilities, presents and evaluates monitoring data from 1-½ years of operation and gives construction costs. The many problems encountered including those associated with cold weather operation are also described to prevent their repetition.

This Project Summary was developed by EPA's Robert S. Kerr Environmental Research Laboratory, Ada, OK, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This project demonstrated the use of an overland flow system in a cold climate. The system was constructed at the Culver duck processing plant, and was located near the Indiana-Michigan border. The major objective of the study was to demonstrate the operation of an inexpensive, simply operated, slaughterhouse wastewater treatment facility, which would meet the 1983 National discharge limitations. A lagoon which collected the overland flow effluent was added to evaluate the effectiveness of batch chemical treatment for phosphate and suspended solids reduction and disinfection. A bentonite seal was used to allow overland flow treatment at a site with highly permeable soils.

Treatment Plant

The wastewater treatment train consisted of five types of treatment units

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connected for series operation as shown in Figure 1. The pretreatment facilities included a fine screen, Hydrocyclonic Rotostrainer, and a gravity grease separator. Inadequate operation of those facilities, which were located in the processing plant, and overloadings resulting from surges of flow, caused frequent grease and solids discharges into subsequent treatment units. These discharges clogged pumps, pipes and orifices, causing pump damage and substantial operating problems.

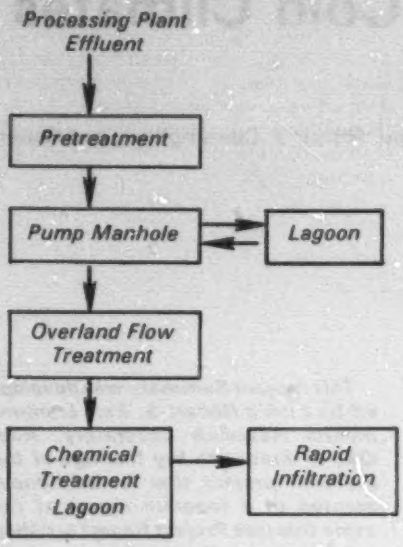

Figure 1. Wastewater treatment plant schematic.

The pretreated effluent flowed by gravity into a manhole where two submersible pumps were located. When the pumps were off, the flow continued by gravity into a large lagoon. The lagoon primarily served as off-line storage during periods when the overland flow treatment plots were not operating. During lagoon storage, however, suspended solids settled, biochemical oxygen demand was reduced, and the wastewater characteristics changed from those of a raw wastewater to those of a lagoon effluent, including high algae concentrations during the summer.

When the pumps were on and wastewater was also flowing from the processing plant, the pretreated effluent was pumped directly to the overland flow plot. During periods when the processing plant was not in operation, the pumps drew down the manhole liquid level so that the lagoon water flowed back into the manhole and was pumped to the overland flow plots. During the last stages of the project, the pumps were removed from the manhole and suspended in the lagoon, to avoid pump clogging when the pretreatment facilities failed. This resulted in only lagoon effluent being pumped to the overland flow plots.

Two overland flow plots were operated in parallel. The influent was applied through a low pressure pipe across the top of the slope. The effluent was collected in a ditch across the foot of the plot and piped through the V-notch weir into the batch chemical treatment lagoon. When the lagoon became full, a floating mechanical aerator was used to mix the lagoon contents. Chemical solutions of sodium hypochlorite for disinfection, followed by alum for phosphate and suspended solids reduction, were added at a point near the aerator for mixing. After chemical addition was completed and large floc particles observed, the aerator was shut off and the contents of the lagoon were allowed to settle.

A pump connected to a floating inlet was used to discharge the treated supernatant into the rapid infiltration area. The rapid infiltration area provided for final effluent polishing and water disposal.

Overland Flow Plots

The overland flow plots were unique and warrant additional consideration. The site was located on a sandy loam soil (U.S. Soil Conservation Service - Oshtemo Series), with a permeability of 5 to 15 centimeters per hour (cm/hour). Since this high permeability would have resulted in rapid infiltration instead of the desired overland flow, the site was modified to allow overland flow treatment.

The site was first stripped of topsoil, then graded to provide a 4% slope downhill and was leveled across the direction of the slope. Bentonite was applied at a rate of 5 kilograms per square meter (kg/m^2) to the graded subsoil and was mixed in to a depth of 5 centimeters (cm). A 15-cm layer of topsoil then was carefully replaced above the bentonite seal and grass was planted. A mixture of Kentucky 31 fescue and perennial ryegrass was used.

Construction costs for the overland flow treatment plots of 0.31 hectares were about $10,000 or $32,000 per hectare in terms of September 1978 dollars. This included the cost of earthwork, bentonite, grass, pumps, and piping but did not include the cost of the land. A detailed description of these costs and the plot construction technique are included in the final report.

Conclusions

The discussion of conclusions has been divided into four sections. First, the overland flow plots are discussed primarily from a consideration of the hydraulics. The performance of the overland flow plots, or effectiveness of treatment, is discussed in the following two sections, divided according to warm weather and cold weather operations. The final section is a discussion of the batch chemical treatment lagoon.

Overland Flow: Hydraulics

The plots were approximately 80 meters (m) long. This is unusually long, about two to three times longer than most other overland flow plots. The additional length was provided because the wastewater strength was expected to be several times greater than actually occurred. The main disadvantage was the high hydraulic loading per unit width of the plot. For example, if two plots were equal in area, but one was one-third as long, the longer plot would have three times as much water flowing along a unit width of the surface. As a consequence of the high hydraulic loading, the grass at the top of the plots died, and that area served mainly to distribute the flow.

Shortcircuiting was most prevalent in the area without grass cover, but also occurred in the downhill grass-covered areas due to surface irregularities. An effective method of control was developed. Small earthen dikes, about 15 cm high and 30 cm at the base, were constructed at 45° or less to the desired downhill direction of flow. Most dikes were 2 m to 5 m long and were constructed during wastewater application to redirect the flow in the desired direction.

Another unique feature of the plots was the void space in the topsoil above the bentonite seal, which needed to be filled with water prior to any overland flow effluent. The flow rate downhill through the topsoil layer was very low. Typically, it took about two days of continuous application to fill the void space

and for effluent to begin flowing from the plot. After that, wastewater flowed along the ground surface with detention times of about 3 hours to 4 hours, much like sites with impermeable soils.

Early in the study, the plots were loaded, similar to other overland flow sites, 8 to 10 hours per day 5 to 7 days per week. This cycle resulted in even more serious problems at the top of the plot. The area was almost always saturated and little effluent was generated. The lower portions of the plots were underloaded and often too dry.

Later in the study, a different cycle was adopted. This cycle provided continuous application for three to five days followed by two or three days of drying, and resulted in hydraulic loadings of 14 to 34 cm/week. The continuous loading for several days followed by extended drying periods proved to be an effective method of operation.

Effluent flow rates, measured during periods of wastewater application, varied from zero, when the plots were dry and evapotranspiration was high, to rates greater than influent flow rates. The high effluent flow rates occurred during periods of rainfall and snowmelt. Table 1 was prepared for one of the plots which had total flows available for all four seasons. Averaged over those longer time periods, total effluent flow was about 40% of the total influent,

Table 1. *Overland Flow Water Balances*

Total Seasonal Water Volume, m^3	Fall	Win	Spr	Sum
Wastewater applied	900	580	1700	1080
Precipitation	90	50	270	50
Total Influent	990	630	1970	1130
Effluent	410	470	780	500
Effluent as percent of total influent	40	75	40	45

except during the winter. The high winter effluent flows resulted from low evapotranspiration rates, because the fields were snow covered, and low infiltration rates, because the ground was frozen.

Overland Flow: Warm Weather Treatment

Waste production at the Culver processing plant was determined on several different days with the average rates shown in Table 2. The USEPA effluent limitations proposed for 1983 duck processors, in terms of averages of daily values for 30 consecutive days, are shown in Table 3. Also included in Table 3, are estimates of maximum concentrations in the Culver wastewater if it is to meet those proposed limitations.

Table 2. *Wastewater Characteristics*

Item	Concentration mg/l	Waste production per duck	
Wastewater Volume	–	70.4	liters
5-Day Biochemical Oxygen Demand	256	18	grams
Chemical Oxygen Demand	398	28	grams
Suspended Solids	170	12	grams
Total Kjeldahl Nitrogen	28	2	grams

During all warm-weather periods, and under widely varying wastewater application schemes (i.e., both 8-16 hours/day at 9 to 25 cm/week, and 3 to 5 days continuous application followed by 2 to 3 days drying at 14 to 34 cm/week), the overland flow plots alone met the limitations shown in Table 3, except when algae problems were encountered. Effluent concentrations of 5-day biochemical oxygen demand (BOD_5); suspended solids and oil and grease during warm-weather operation were all typically about one-half of the limitations shown in Table 3. Table 4 shows average effluent values for the fall and summer periods. The summer period has been further divided to show the effect of high influent algae concentrations. During the early summer period there was no substantial influent algae. However, algae produced in the lagoon resulted in high influent algae concentrations during the mid-summer periods, and a reduction in effluent quality. The poor quality effluent was almost a direct result of the presence of influent algae. Effluent samples which were filtered to remove algae, exhibited characteristics very nearly the same as occurred during periods when algae was not present in the influent.

Effluent analyses were made during several short intense rainfall periods when wastewater was being applied and effluent was being produced. Although flow rates increased, no substantial change in effluent concentrations was observed.

Overland Flow: Cold Weather Treatment

Cold weather treatment refers to the winter and early spring periods when temperatures averaged -6°C and 5°C, respectively. Soil temperature appeared to be the most important variable affecting effluent quality. The presence or absence of snow cover was very important in determining the effect of air temperatures on soil temperatures.

Operation was begun during the coldest month of the year, January, after two months of no operation. At the beginning of the January operation, the overflow plot was covered with snow at a depth of about 1 m. The wastewater applied was either raw wastewater at about 20°C or lagoon effluent at about 5°C. All wastewater was applied during the day (8 to 16 hours) and the plot was allowed to rest during the night. As a result of the daily loading, the soil was saturated all the time because the nighttime drying periods were insufficient to remove the water. Also, hydraulic loading rates were high, about 15 cm/week, which probably contributed to reduced effluent quality. In retrospect, the cyclic operation adopted during the following summer, continuous application for several days followed by several days of rest, would have been a better choice.

Air temperatures did not exceed 0°C during the first three weeks after start up. However, the snow cover across the top 15 m of the plot was melted by the influent wastewater, and temperatures

Table 3. Effluent Limitations

Item	Proposed 1983 Limitation	Estimated Concentrations for Culver Duck Farm†
5-Day Biochemical Oxygen Demand	0.39 kg/kkg LWK*	33 mg/l
Suspended Solids	0.46 kg/kkg LWK	39 mg/l
Oil and Grease	0.26 kg/kkg LWK	22 mg/l
Ammonia Nitrogen	4.0 mg/l	4 mg/l

*Live weight killed. kg/kkg LWK is equivalent to lb/1000 lb LWK.
†Based on 70 liters/duck wastewater production, 50% water loss during overland flow treatment and a live weight of 3 kilograms per duck.

Table 4. Average Warm Weather Overland Flow Effluent

Wastewater Characteristic	Fall	Summer Early	Summer Mid
5-day Biochemical Oxygen Demand, mg/l	7	16	38[b]
Suspended Solids, mg/l	n.a.	12	45[c]
Total Nitrogen[a], mg/l as N	4	6	11
Total Phosphate, mg/l as P	2.2	2.3	
Oil and Grease, mg/l	n.a.	7	

[a]Sum of organic, nitrite, nitrate, and ammonia nitrogen.
[b]When filtered to remove algae, the average was 17 mg/l.
[c]These suspended solids were primarily algal cells.

were observed as high as 4°C in the top 5 cm of soil. Below that warmer soil, the ground remained frozen. Shortly after each period of wastewater application ended, ice formed across the top 15-m area. However, during wastewater application no freezing occurred even when air temperatures dropped to -15°C, except occasionally when the colder lagoon effluent was being applied.

Below the snow cover, a thin layer of soil remained at temperatures between 0°C and 2°C. Below that warmer soil layer, the soil remained frozen. Over the lower one-third of the plot, there was a layer of slush about 2 cm to 5 cm deep. The effluent temperatures were never observed to be greater than 1°C and typically were less than 0.5°C.

During that period of snow cover, the start up period, the BOD_5 in the effluent gradually decreased from about 240 mg/l to about 95 mg/l. Cold weather did not prevent microbial activity. Clusters of what appeared to be white fungi were observed. The fungi probably dominated other microbes due to their ability to adapt to the cold, and their ability to extend hyphae to the water surface to obtain oxygen. Psychrophilic fungi are known to grow and oxidize carbon in temperatures near and lower than 0°C.

The fairly rapid improvement of BOD_5 observed after start up, was probably due to increases in microbial population and not increases in oxidation rates of individual microbes. It is unclear how much greater the improvement would have been if the snow covered conditions had continued for a longer period of time. However, warmer weather, including rain, occurred and the snow cover was lost. Effluent BOD_5 finally reached effluent limitations shortly after the snow melted.

After the snow melt period, the average air temperature was 4°C for about one month. During that period, air temperatures fluctuated from above freezing to below freezing. Effluent BOD_5 values were very sensitive to air temperatures. A fairly linear relationship between air temperatures and effluent BOD_5 values was observed. In general, effluent BOD_5 values did not meet effluent limitations at air temperatures below 0°C, just met them at 0°C to 5°C, and were well within the limitations above 5°C. One interesting observation was made as average air temperatures continued to increase. Following a week when daily mean air temperatures averaged 11°C, mean daily temperatures dropped to -2°C on one day and -6°C on the next. Effluent BOD_5 increased from the warmer weather values of about 10 mg/l to over 50 mg/l on the second day of the cold period. That increased sensitivity to cold temperatures after a period of warm temperature probably was due to a change in the soil microbial population. Mesophilic bacteria and other moderate temperature microbes probably gain the ecological advantage during the warm spell. The ability of the newly dominant mesophilic microbes to oxidize organics was seriously hindered in sub-freezing temperatures.

Effluent suspended solids concentrations generally met effluent limitations during the cold weather period. Nitrogen removals were generally poor during that same period. A major spill of anhydrous ammonia from the plant refrigeration system into the wastewater also seriously interfered with the nitrogen study. Some nitrogen removal did occur during the cold weather. The mechanisms of nitrogen removal were uncertain.

During snow melting periods, effluent BOD_5, suspended solids and ammonia concentrations were all relatively high. However, effluent from the adjacent overland flow plot, which had received no wastewater during the winter, was essentially the same as the effluent from the plot which had operated during the winter. The total mass of effluent pollutants associated with the melted snow was less than the total mass which would have been applied in about 3 cm of a mixture of raw wastewater and lagoon effluent.

The average effluent characteristics are shown in Table 5 for the winter period, when snow cover existed and spring, a time after snowmelt had occurred.

Chemical Batch Treatment Lagoon

Overland flow treatment resulted in very little phosphate reduction during cold weather and warm operation. However, effective phosphate reduction was provided during chemical batch treatment in the lagoon located at the foot of the overland flow plots. Disinfection was also provided in that lagoon.

Table 5. Average Cold Weather Overland Flow Effluent

Wastewater Characteristic	*Winter*	*Spring*
5-day Biochemical Oxygen Demand, mg/l	*135*	*22*
Suspended Solids, mg/l	*40*	*15*
Total Nitrogen, mg/l as N*	*54*	*11*
Total Phosphate, mg/l as P	*2.8*	*2.6*
Oil and Grease, mg/l	*7*	*n.a.*

**Sum of organic, nitrite, nitrate, and ammonia nitrogen.*

A complete analysis was made on one batch treatment. The treatment included addition of a sodium hypochlorite solution resulting in a 5 mg/l chlorine dosage. Mixing was provided, using the floating mechanical aerator, during chlorine addition and was continued for 30 minutes. Chlorine residuals both total and free, were greater than 3 mg/l after the 30-minute mixing period. An alum solution was then added to the mixing lagoon over a period of one hour, which resulted in an aluminum dosage of 50 mg/l. After 10 minutes more of mixing, the aerator was shut off, and the lagoon contents allowed to settle for 1.5 hours. Table 6 compares the lagoon contents before and after treatment.

Recommendations

Overland flow should be considered as a wastewater treatment alternative at sites with permeable as well as impermeable soils. Application of more than 5 kg/m^2 of bentonite is recommended to ensure a better percolation barrier at future sites.

In systems requiring increased phosphate removal disinfection, or a greater assurance of suspended solids reduction, a small lagoon should be constructed to collect the overland flow effluent. This provides opportunity, using simple batch chemical treatment and controlled discharge, to improve effluent quality. This relatively inexpensive treatment is well suited for use in conjunction with overland flow.

Research should be undertaken to determine optimum wastewater application cycles. Experience at the site suggests that 24 hours per day application for several days, followed by two or three days of drying, is a cycle which deserves future investigation.

Winter storage is needed. However, winter operation needs to be investigated further. This investigation should concentrate on overland flow treatment on snow covered plots, because substantially higher quality effluents are likely with the snow cover to protect the soil from very low and highly fluctuating temperatures. The study indicated that some degree of treatment is possible in the winter, but that loading rate must be reduced, and unsatisfactory effluent returned for further treatment. Winter wastewater application is recommended to develop a microbial population capable of treating the wastewater immediately following the spring thaw.

Further investigations are necessary to determine the effect of sudden decreases in temperature in late fall and early spring. It may be necessary to stop wastewater application during these short cold spells.

Application of lagoon wastewater to an overland flow plot should be avoided if possible. Operators of systems using storage lagoons prior to overland flow treatment are recommended to by-pass these lagoons during peak algae growing periods. Removal of sufficient grit and solids to prevent pump and nozzle plugging is recommended when lagoons are by-passed or raw wastewater is applied directly to overland flow plots.

Table 6. Lagoon Chemical Batch Treatment

Wastewater Characteristic	*Treatment Before*	*After*
5-day Biochemical Oxygen Demand, mg/l	*38*	*7*
Suspended Solids, mg/l	*29*	*20*
Ammonia Nitrogen, mg/l	*7.2*	*7.0*
Nitrate plus Nitrite Nitrogen, mg/l	*0.3*	*0.1*
Total Kjeldahl Nitrogen, mg/l	*12.9*	*8.5*
Total Phosphate, mg/l as P	*2.8*	*0.4*
Inorganic Phosphate, mg/l as P	*2.1*	*0.1*
Coliforms	*n.a.*	*0*
pH	*n.a.*	*6.5*

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The complete report, entitled "Overland Flow Treatment of Poultry Processing Wastewater in Cold Climates," (Order No. PB 81-213 225; Cost: $12.50, subject to change) will be available only from:

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